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STATUS OF LOBSTER STOCKS IN THE NORTHWESTERN HAWAIIAN ISLANDS, 1991

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ABSTRACT

Analysis of commercial logbook and research data indicated that low recruitment of spiny lobster, *Panulirus marginatus*, to Maro Reef continued in 1991. Spiny lobster landings at Maro Reef were correlated with fluctuations in sea level data from Midway Islands and French Frigate Shoals 4 years earlier. Evidence of poor spiny lobster recruitment to a commercially unexploited area (Laysan Island) supports the hypothesis that spiny lobster recruitment to portions of the Northwestern Hawaiian Islands (NWHI) is affected by perturbations in average mesoscale oceanographic conditions. Indications that the spiny lobster stocks were nearing overexploitation prompted an emergency action by the Western Pacific Regional Fishery Management Council, which closed the NWHI commercial lobster fishery 8 May-11 November 1991. Fishing recommenced on 12 November and continued through the end of the year. Total fishing effort in 1991 was 296,000 trap-hauls, resulting in 35,000 slipper lobster, *Scyllarides squammosus*, and 131,000 spiny lobster. Because of continued poor recruitment to Maro Reef, overexploitation of the NWHI spiny lobster stocks could result if fishing pressure is not controlled in the future. The Crustacean Fishery Management Plan was amended to create a limited entry fishery and impose an annual catch quota and closed season. A catch per unit effort (CPUE) model was fit to commercial CPUE data to estimate mortality, recruitment, and catchability for the NWHI lobster stocks. These estimates were used in an iterative CPUE model to derive a catch curve which would on the average result in an annual commercial CPUE of 1.0 lobster/trap-haul. The 1991 commercial catch and effort data were used with the model-based biological parameters to simulate lobster population response to the closed fishing season and to estimate a commercial CPUE for the first month of the 1992 fishing season. This value was used in the CPUE-based catch curve to calculate a preliminary estimate of the 1992 slipper and spiny lobster quota: 750,000 lobsters.

INTRODUCTION

This is the seventh annual report on the status of lobster stocks in the Northwestern Hawaiian Islands (NWHI). Research and commercial logbook data were used to examine the fishery and population dynamics of spiny lobster, *Panulirus marginatus*, and slipper lobster, *Scyllarides squammosus*.

RESEARCH AGE-FREQUENCY DATA

The NOAA ship *Townsend Cromwell* conducted research trapping operations at Laysan Island, Maro Reef, and Necker Island in the NWHI from 24 June to 21 July 1991. Length-frequency data were collected at quadrats standardized temporally, spatially, and by gear type at these three areas. Length frequencies of spiny lobster were converted to age frequencies by applying a growth curve estimated by Polovina and Moffitt (1989). The catch per unit effort (CPUE) for each age class was calculated by dividing the total number in each age class by the total number of traps for each bank. Based on this growth curve, recruitment of legal-sized spiny lobster to the fishery is estimated to occur at approximately age 3.

By using age-specific CPUE values as an indicator of relative abundance, recruitment of spiny lobster to specific banks can be examined. At Maro Reef from 1985 through 1988, CPUE was highest for age-3 spiny lobster. Commercial effort at Maro Reef remained fairly constant during 1985-89 (average effort, 350,000 trap-hauls); the associated high CPUE values of age-3 lobster at Maro Reef indicate recruitment remained stable during the time period. By 1990, a dramatic decrease in CPUE for all age classes at Maro Reef was apparent (Fig. 1). The CPUE values for age-2 and age-3 spiny lobster dropped 90% from 1988 to 1990. Low CPUE values persisted in 1991; CPUE values for age-2 and age-3 lobster declined another 80% and 67%, respectively. The low CPUE values during 1990-91 were not an effect of commercial exploitation alone, as commercial effort at Maro Reef dropped 45% from 1988 to 1990 and another 80% in 1991. The dramatic reduction in CPUE of all age classes at Maro Reef in 1990 may be attributed to poor post-larval recruitment of spiny lobster to Maro Reef beginning in 1986, with an associated fishing down of the available population. Further reduction in age-specific CPUE of age-2 and age-3 spiny lobster in 1991, and the associated very low commercial CPUE prior to the 1991 research cruise, indicate that poor recruitment of spiny lobster to Maro Reef continued during 1987-88.

Fluctuations in the commercial catch of spiny lobster at Maro Reef are correlated with variations in sea level differences between French Frigate Shoals (FFS) and Midway Islands 4 years earlier (Polovina and Mitchum In review) (Fig. 2). The oceanographic dynamics of lobster larvae transport to and from the NWHI remain unknown; however, the strong correlation between sea level and Maro Reef catches provides a method of preliminary catch forecasting. Based on this correlation, spiny lobster catches at Maro reef should improve in 1992.

Laysan Island has been closed to commercial harvest since the beginning of the commercial fishery. Based on age-specific CPUE values obtained by the National Marine Fisheries Service (NMFS) in 1977, prior to the onset of the NWHI commercial fishery, the age frequencies of spiny lobster at Laysan Island had a relatively normal distribution (Fig. 3). Age-specific CPUE values from the 1985 and 1986 research surveys indicate the relative abundance of age-2,-3, and -4 spiny lobster remained fairly constant. However, by 1991, results indicated very low age-2 and -3 CPUE values and a reduction in the age-4 CPUE value. The reduction in age-specific CPUE values in the absence of commercial fishing effort at Laysan Island is consistent with the hypothesis that recruitment of spiny lobster to portions of the NWHI fluctuates in response to cyclical perturbations in the average mesoscale current regime (Polovina and Mitchum In review). The increase in age-5 and -6 CPUE may be due to density-dependent biological or gear selection factors.

Recruitment of spiny lobster to Necker Island appeared to remain stable during 1985-91. Age-specific CPUE values for age-2 and -3 lobster remained high and fairly constant (Fig. 4). The reduction in CPUE of age-3 lobster in 1990 and 1991 may be an effect of increased commercial effort directed at Necker Island in response to declining catches at Maro Reef. The high CPUE of age-2 lobster in 1991 indicates post-larval recruitment was still good in 1989, and that recruitment to the fishery should be good during the 1991-92 season. These data suggest recruitment mechanisms of spiny lobster to Necker Island are not affected negatively by the oceanographic dynamics associated with the FFS-Midway sea level fluctuations.

RESEARCH TRAP COMPARISON

Wire mesh traps were the standard lobster gear used in the NWHI when the commercial fishery began. During the early 1980s, the commercial fishery began setting black plastic traps, eventually using them exclusively. Since the inception of the NMFS research sampling program, the standard wire traps have been used; however, their availability has declined, ultimately leading to the use of plastic traps for research sampling in the future. This presents a data-base problem as the selection curve may differ between wire and plastic traps (Polovina 1985), confounding time series data collected with the two gear types. To examine the feasibility of using plastic traps to provide data that are comparable with the earlier data base, the catch rates of plastic versus wire traps were compared.

Both trap types were fished at Maro Reef and Necker Island during the 1991 research cruise. The 1991 data were combined with data from an NMFS gear comparison study conducted in 1985 at Laysan Island, Maro Reef, and Necker Island. Catch rates of spiny lobster in wire traps were linearly correlated to spiny lobster catch rates in plastic traps for both legal and sublegal lobster ($P_L < 0.01$, $r^2 = 0.98$; $P_{SL} < 0.01$, $r^2 = 0.92$) (Fig. 5). To determine whether selection differences existed between the two trap types, the slopes of the above regression lines were tested against a regression coefficient of 1.0, which represents equal catch rates between the two trap types. Catch rates of legal lobster in wire and plastic traps were not significantly different across the CPUE values tested ($P > 0.64$). However, catch rates of sublegal lobster in wire traps were found to be significantly less than catch rates of sublegal lobster in plastic traps ($P < 0.01$). Catch rate of sublegal spiny lobster in plastic traps was over twice that of wire traps. Based on the highly significant correlation between catch rates in the two trap types and the insignificant difference between catch rates of legal lobster in the two trap types, direct comparisons may be made between legal lobster catch rates in plastic traps and in wire traps. However, sublegal catch rates in plastic traps must be converted to a standard CPUE value:

$$CPUE_{plastic} = 0.24 + (2.33 * CPUE_{wire}) \ . \qquad (1)$$

COMMERCIAL FISHERY DATA

Because of indications that recruitment to banks in the northwestern portion of the NWHI had fallen dramatically since 1988, the NMFS recommended fishing effort be reduced in 1991 to allow the stocks to recover (Polovina 1991). Continued poor commercial catches during the first half of 1991 prompted an emergency action by the Western Pacific Regional Fishery Management Council (WPRFMC), which closed the commercial lobster fishery in the NWHI from 8 May through 11 November 1991.

Because of the emergency closure of the fishery, commercial fishing effort in 1991 was divided into two time periods: 1 January-8 May and 12 November-31 December. Most of the fishing effort (expressed as the number of trap-hauls) in 1991 occurred at Necker Island (37%) and Gardner Pinnacles (49%).

During the first period, 123,000 legal-sized spiny and slipper lobsters were caught in 212,828 trap-hauls (CPUE = 0.58); of these, 95,000 were legal spiny lobster (CPUE = 0.45). This represents a 71% increase in total effort and a 17% decrease in spiny lobster CPUE from the same period during 1990 (Landgraf 1991). During the second period, 43,514 legal spiny and slipper lobsters were caught in 83,055 trap-hauls (CPUE = 0.52); of these, 36,139 were legal spiny lobster (CPUE = 0.44). Yearly catch and effort data are presented in Table 1 and Figure 6.

Sublegal spiny lobster accounted for an estimated 60% of the total catch from Necker Island and Gardner Pinnacles during the January-May period, and approximately 30% of the total catch during the November-December period.

The trend beginning in 1989 of reduced commercial lobster catch and CPUE at Maro Reef continued through May 1991. There was some indication that catches at Maro Reef were improving late in 1991, however, as average legal spiny lobster CPUE increased sixfold during the second period of 1991.

LOBSTER POPULATION MODEL

Population parameters were estimated using commercial NWHI lobster fishery catch and effort data from 1983 through 1991. The data were fit to a dynamic CPUE-based model for exploited populations. This methodology is appropriate since temporal fishing effort in the NWHI fluctuates considerably and catch-at-age data for this fishery are currently unavailable (Polovina 1991). This model expresses monthly CPUE ($CPUE_t$) as a function of CPUE in the same month of the previous year $CPUE_{t-12}$, cumulative effort over the 12-month period from month t-12 to t-1 (E_t), annual instantaneous natural mortality (M), annual recruitment to the fishery (R), and catchability (q) as

$$CPUE_t = Re^{-M/2\ -qEt/2} + CPUE_{t-12}\ e^{-M\ -qEt} \ . \qquad (2)$$

Model-based parameters were estimated using an iterative nonlinear least squares method which minimizes the square root of the residual sums of squares. The model assumes constant recruitment and catchability. By examining the temporal pattern of residuals from the model fit CPUE values, inferences may be made regarding monthly variation in catchability or recruitment.

To create a valid time series of CPUE data which could be used in Equation (2), monthly catches of both lobster species were pooled across all banks. This was necessary because of fluctuations in fishery dynamics resulting from temporal and spatial changes in fleet effort and primary target species. The model was fit to the pooled commercial CPUE data from 1984 through 1991 (Fig. 7). The resulting parameter estimates were R = 1.46 x 10^6, M = 0.495, q = 9.14 x 10^{-7}, and F = 0.27. Based on these parameters, under average conditions, an estimated 1.5 million spiny and slipper lobsters recruit to the fishery annually, with a survival rate in the absence of fishing of approximately 60% per year. Using the 1991 mean commercial CPUE value of 0.45 spiny lobster/trap-haul, the exploitable spiny lobster population in the NWHI was estimated to be 500,000 individuals during the 1991 fishing season.

SPAWNING STOCK BIOMASS

The biological parameters estimated by fitting Equation (2) to commercial CPUE data were used with the 1991 commercial fishing effort in a standard yield per recruit model to estimate the spawning stock biomass per recruit (SSBR) resulting from the 1991 commercial fishing pressure. This value is compared to a pre-exploitation SSBR value to calculate a measure of estimated spawning success or spawning potential ratio (SPR). This value, which is simply the exploited SSBR to unexploited SSBR ratio, is used by the WPRFMC to determine whether the NWHI lobster stocks are approaching a level of recruitment overfishing. Goodyear (1989) suggests that for some stocks, recruitment overfishing may occur when the SPR value falls below 0.20. The WPRFMC has adopted an SPR value of 0.20 as the minimum threshold for the NWHI lobster fishery.

The result of fitting the SSBR model to the commercial fishing effort in 1991 (296,000 trap-hauls) results in an SPR value of 0.61. This value by itself seems to indicate that the fishery was under-exploited during January-May and November-December 1991. However, the parameters in the SSBR model are based on a long-term average of population conditions, so under average recruitment conditions, 296,000 trap-hauls would not produce a serious decline in the lobster spawning biomass. A more informative measure of spawning biomass should incorporate recruitment fluctuations, as some of the NWHI banks have experienced low recruitment since 1987.

If research CPUE data are available for a given year, an index of spawning stock biomass may be calculated. This value is expressed as the ratio of the current year's spawning stock biomass (in kilograms per trap-haul) to unexploited spawning stock biomass. The ratio of spawning stock biomass in 1991 to pre-exploitation levels is given in Table 2. Spawning biomass at Necker Island and Maro Reef in 1991 was approximately 20% of the pre-exploitation level and is currently at the lowest level since the start of the commercial fishery. Spawning stock biomass at Maro Reef has fallen drastically since 1988 and continued to decline in 1991. The relationship between spawning biomass and lobster recruitment to the fishery is unclear; however, the low spawning biomass index values observed at Necker Island and Maro Reef since 1988, in combination with the age-specific CPUE data, indicate biological recruitment fluctuations and fishery exploitation have substantially impacted the spawning biomass in the NWHI.

1992 COMMERCIAL FISHERY QUOTA METHODOLOGY

In response to the declining NWHI commercial lobster catches, the Crustacean Fishery Management Plan was amended to create specific management measures to protect against potential overfishing of the NWHI lobster stocks. These measures include a limited entry system for vessel fishing permits, an annual closed season (January-June), and an annual fleet harvest quota. The fishing industry and the WPRFMC determined the annual quota should be set at a level which would permit an annual fleet CPUE of 1.0 lobster per trap-haul and allow the stocks to rebound.

To simulate the effect of an annual closed season on the NWHI lobster population, Equation (2) was modified to account for a 6-month closure period during which the population could rebound. The model was used iteratively to determine the number of lobsters which could be taken under average recruitment conditions while allowing the stocks to rebound to sustainable levels and provide an average combined legal spiny and slipper lobster CPUE of 1.0 during the fishing season. The resulting quota equation was presented in Amendment 7:

$$Quota_i = Catch_{(opt)} + [N_i - N_{(opt)}] \ ; \qquad (3)$$

where Quota_i = the combined spiny and slipper lobster quota in year i, $\mathrm{Catch}_{(opt)}$ = 960,000, and $N_{(opt)}$ = 1,400,000. N_i will be determined from the equation

$$N_1 = CPUE_i / q \ ; \qquad (4)$$

where q is an independently derived estimate of catchability, and CPUE_i is the combined legal spiny and slipper lobster CPUE at the beginning of a particular fishing season. CPUE_i may be derived from research or fishery data.

PRELIMINARY QUOTA FORECAST

Lobster recruitment to the NWHI varies considerably between banks. Recruitment to Necker Island has remained fairly constant since 1985, while recruitment to Maro reef has declined from pre-1989 levels and remains low. Maro Reef historically accounts for approximately 40% of the catches from the NWHI. Based on the FFS-Midway sea level to commercial catch correlation and research catch-at-age data, poor recruitment to Maro Reef is expected to continue through mid-1992. Therefore, the model-based recruitment value used in the preliminary quota estimation procedure was reduced 40% to account for lower-than-average lobster recruitment to the NWHI in 1991-1992.

To provide a preliminary estimate of the July-December 1992 NWHI commercial lobster quota, NWHI commercial catch and effort logbook data from November-December 1991 and estimated commercial landings during January-February 1992 were used with CPUE model based estimates of lobster recruitment and mortality to predict a CPUE value for July 1992 ($CPUE_i$). This value (1.08) was then used in Equation (3) to estimate the preliminary 1992 NWHI commercial quota of 750,000 spiny and slipper lobsters. It must be noted that lobster larval transport and recruitment processes are dynamic and have been shown to fluctuate in response to changes in oceanographic processes related to El Niño Southern Oscillation (ENSO) events. These events are cyclical, and the magnitude and temporal scale of their effect on lobster population dynamics remains unknown. Thus, determining the extent of the recovery of portions of the NWHI affected by the last ENSO event (1986-87) is problematic. The biological parameters estimated using the CPUE model are based on long-term population average, and are as yet untried for short-term forecasting. Therefore, the model-based estimate of the July 1992 $CPUE_i$ and associated commercial quota are highly preliminary, so for management purposes, they should be used with caution as the actual July 1992 $CPUE_i$ could vary considerably.

Although the final estimate of $CPUE_i$ may differ from the pre-season estimate as derived from Equation (2), the relationship between $CPUE_i$ and the final $Quota_i$ as derived in Equation (3) is linear and can be used to predict the final in-season $Quota_i$ based on any given $CPUE_i$ as derived from commercial and research data at the beginning of the July-December NWHI lobster season (Fig. 8).

A final in-season quota will be determined from Equation (3), where $CPUE_i$ is estimated from a combination of pre-season research data and commercial logbook data from the first month of fishing. Research and commercial CPUE data are highly correlated (Fig. 9); therefore, the estimate of $CPUE_i$ used in Equation (4) may be adjusted by using research data to account for uneven commercial effort during July of any specific year.

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Table 1.--Annual landings of spiny and slipper lobster (1,000s), trapping effort (1,000s trap-hauls), and the percentage of spiny lobster in the landings, 1983-91.[a]

	Spiny lobster	Slipper lobster[b]	Total lobster	Effort	CPUE	Percent spiny lobster
1983[c]	158	18	176	64	2.75	90
1984	677	207	884	371	2.38	78
1985	1,022	900	1,902	1,041	1.83	57
1986	843	851	1,694	1,293	1.31	54
1987	393	352	745	806	0.92	57
1988	888	174	1,062	840	1.26	84
1989	944	222	1,166	1,069	1.09	81
1990	591	187	777	1,182	0.66	76
1991[d]	131	35	166	296	0.56	79

[a]Data are provided to the National Marine Fisheries Service as required by the Crustacean Fishery Management Plan of the Western Pacific Regional Fishery Management Council and are compiled by the Fishery Management Research Program, Honolulu Laboratory.

[b]Slipper lobster landings in 1984-87 are 72% of those reported. The adjustment was made to account for a minimum size change in 1987.

[c]April-December 1983.

[d]January-May, November-December 1991.

Table 2.--An index of spawning stock biomass (kg/trap-night) for spiny lobster.

	Index by year						
	1977	1986	1987	1988	1990	1991	1991/1977
Necker Island	2.45	0.86	0.83	1.24	0.65	0.65	**0.27**
Maro Reef	2.14	1.26	1.74	1.71	0.36	0.20	**0.10**

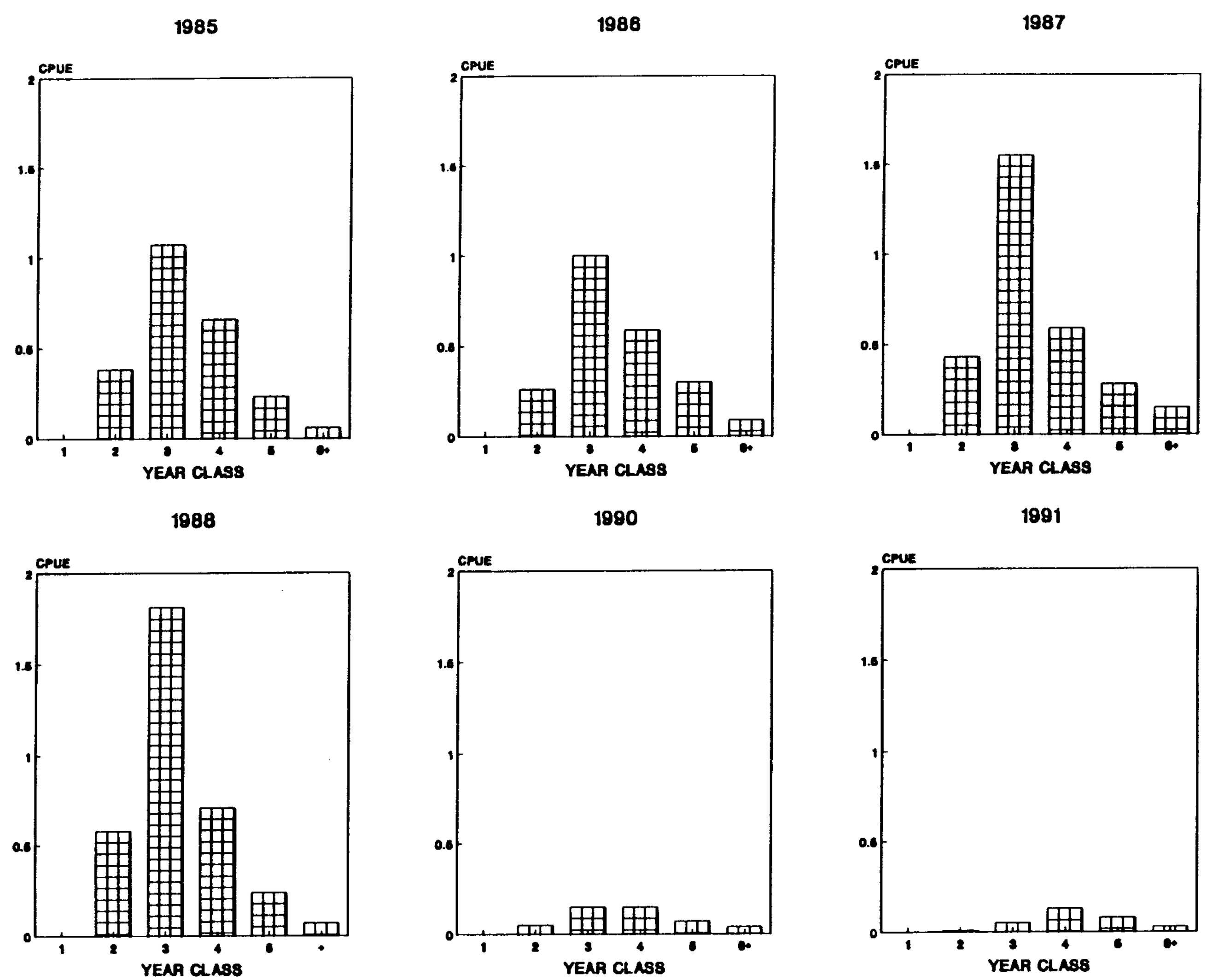

Figure 1.--Catch per unit effort (CPUE) for each age class of spiny lobster, Maro Reef, 1985-88, 1990-91.

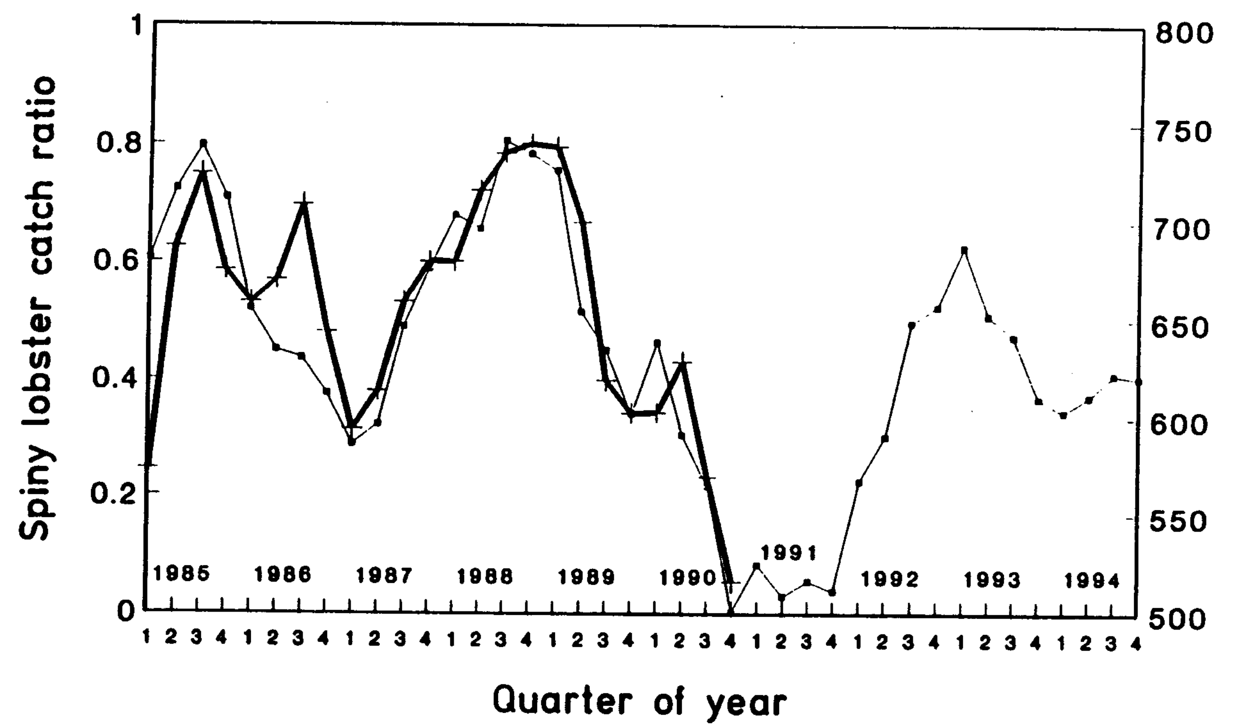

Figure 2.--Three-quarter moving average of the ratio of quarterly landings of spiny lobster at Maro Reef to quarterly landings at Maro Reef and Necker Island (+) overlayed with the 3-quarter moving average of French Frigate Shoals (FFS)-Midway sea level advanced by 4 years (■) (from Polovina and Mitchum In review).

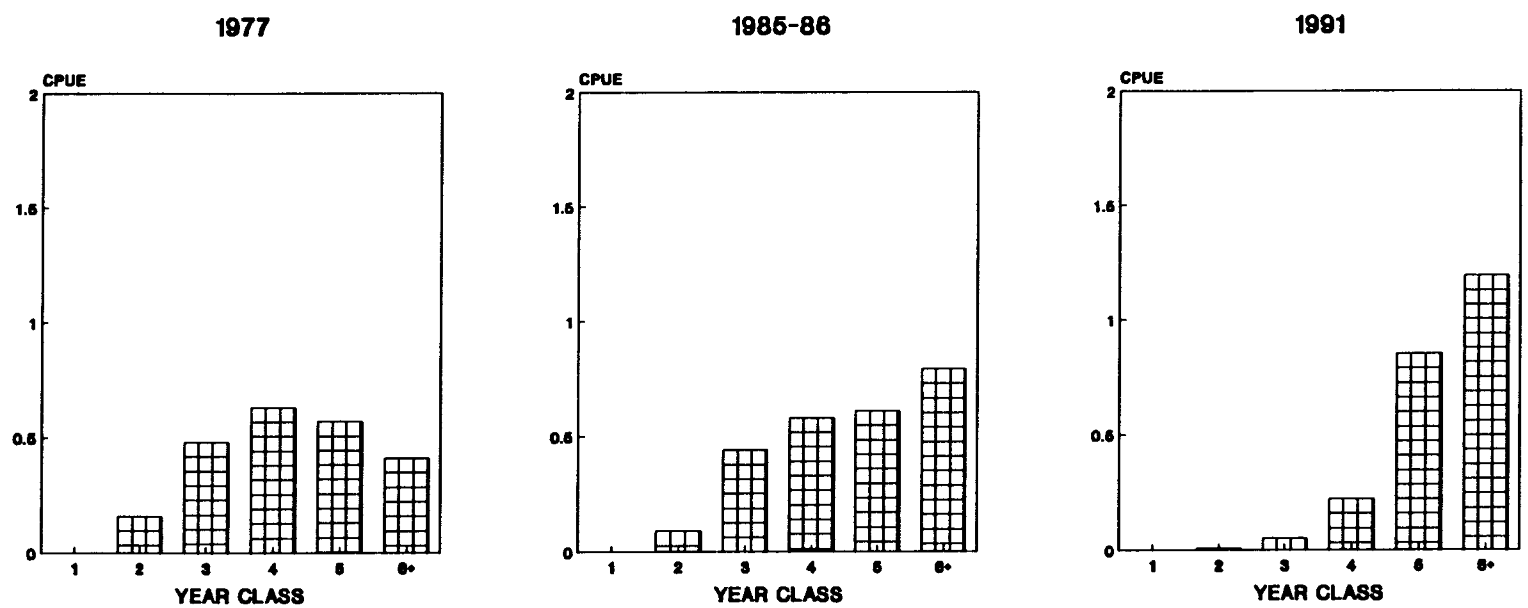

Figure 3.--Catch per unit effort (CPUE) for each age class of spiny lobster, Laysan Island, 1977, 1985-86, and 1991

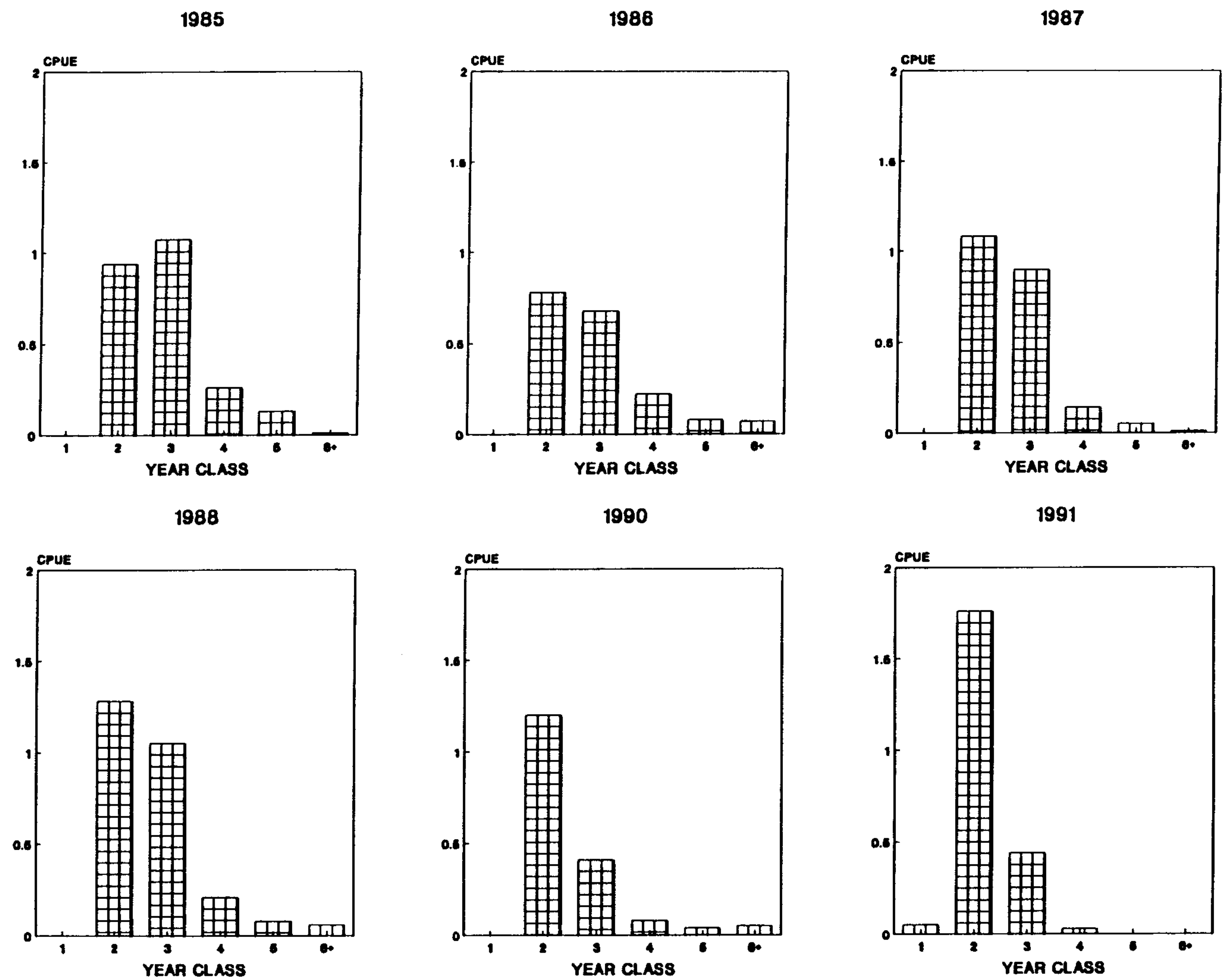

Figure 4.--Catch per unit effort (CPUE) for each age class of spiny lobster, Necker Island, 1985-88, 1990-91.

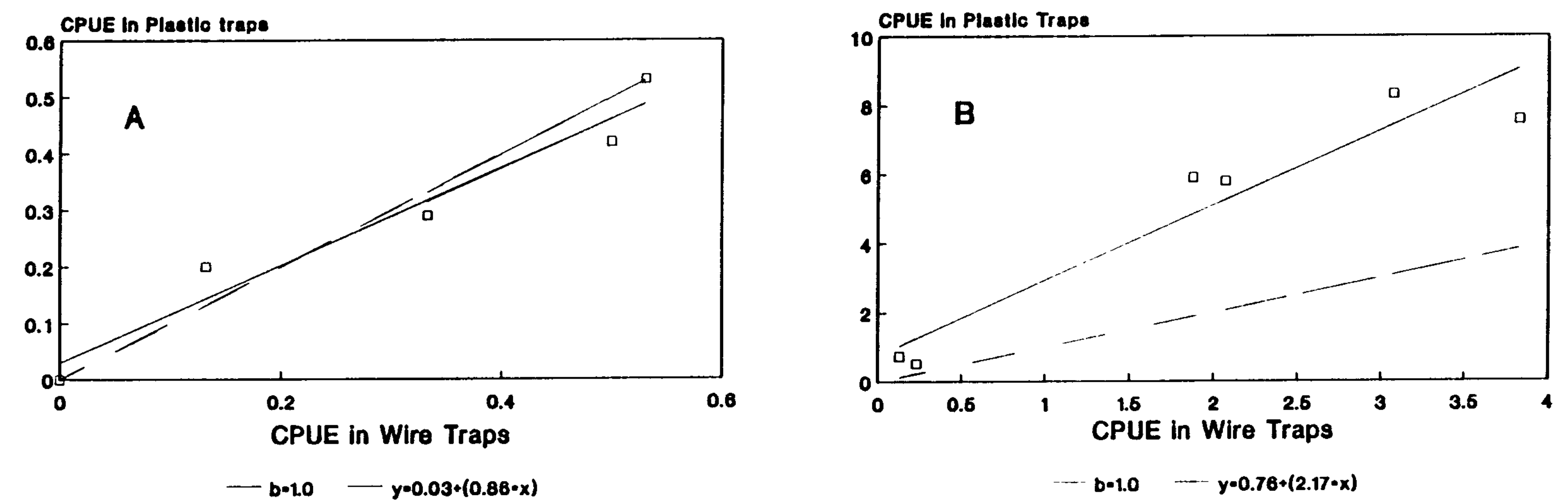

Figure 5.--Comparison of catch per unit effort for (A) legal and (B) sublegal spiny lobster caught in plastic versus wire traps (1985 and 1991 research data combined).

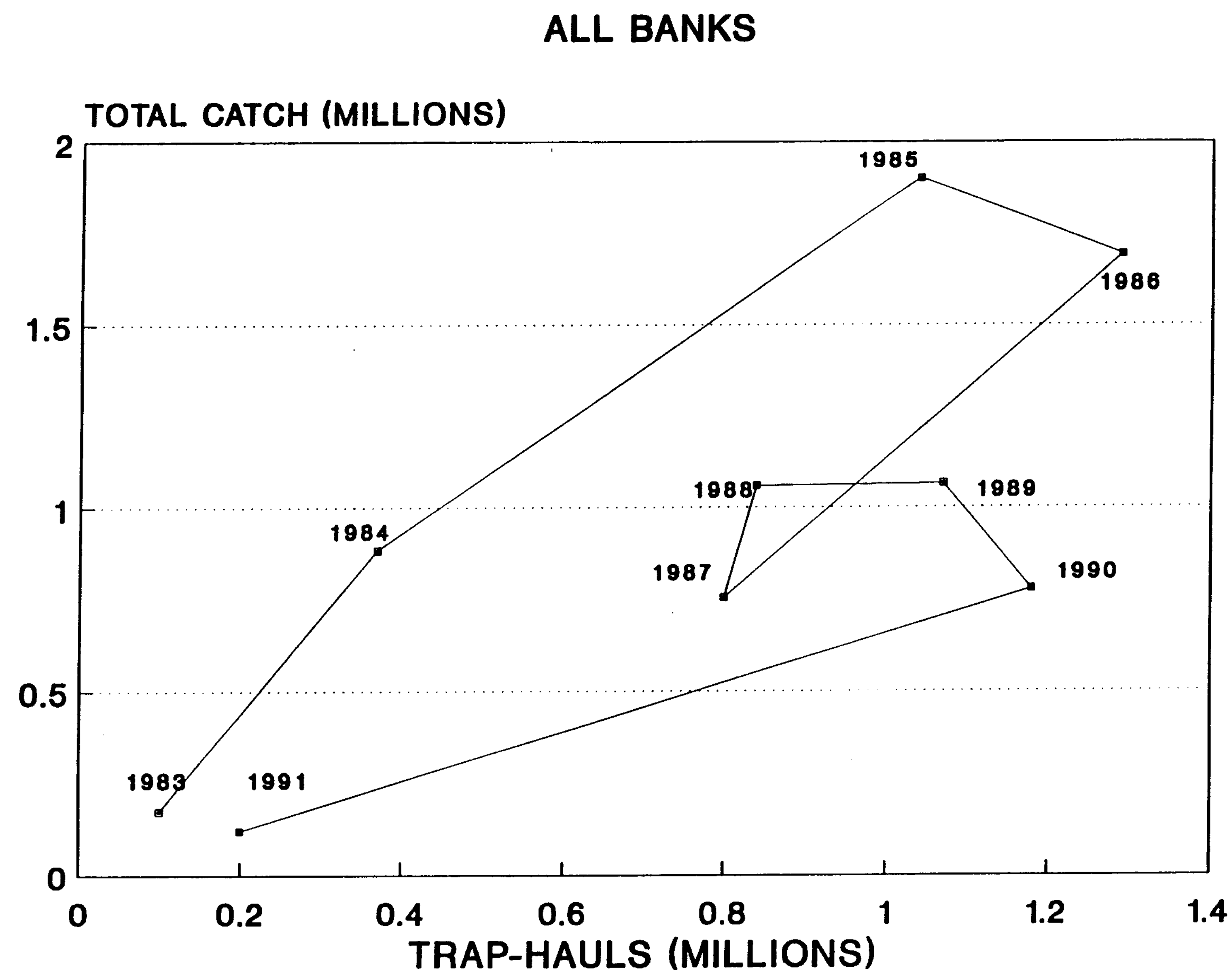

Figure 6.--Catch and effort, based on commercial logbooks, for all banks in the Northwestern Hawaiian Islands (combined), 1983-91.

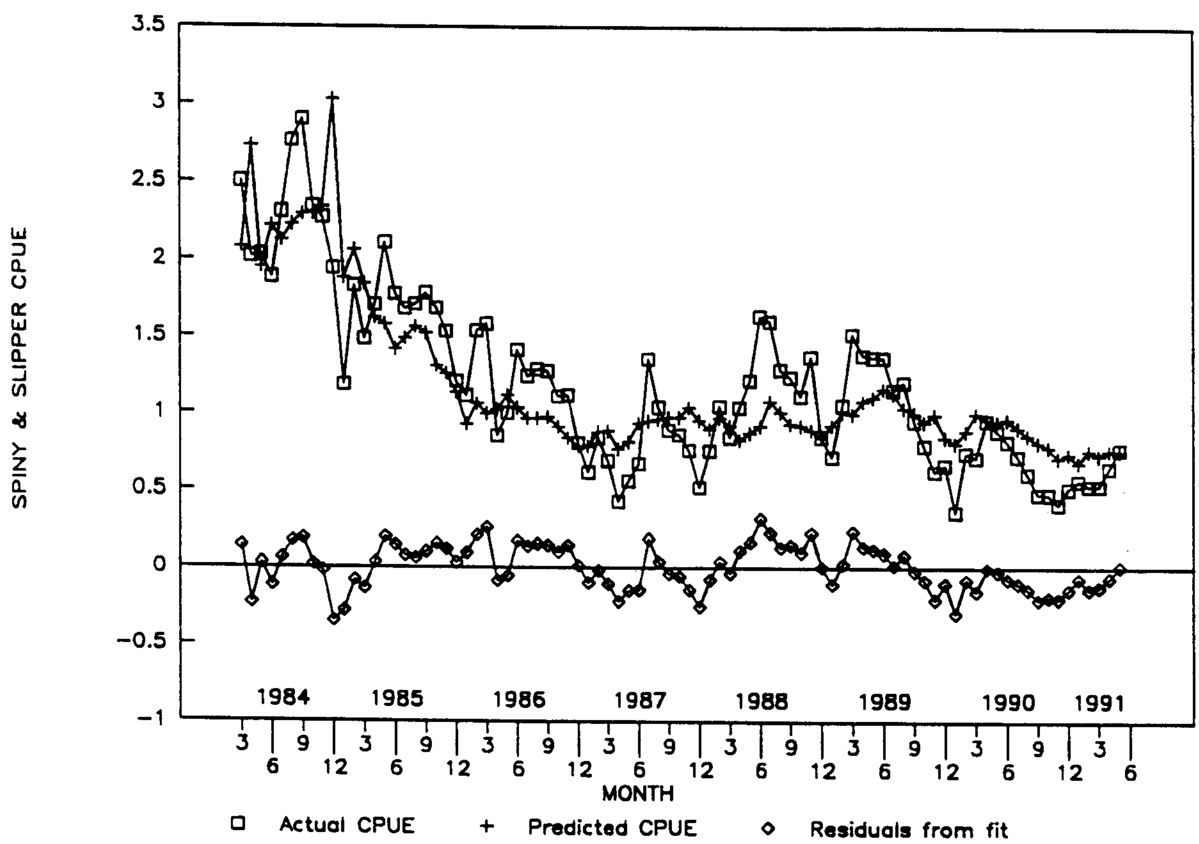

Figure 7.--Monthly catch per unit effort (CPUE) and fit of CPUE model for spiny and slipper lobsters based on commercial fishery data, 1983-91. Residuals are the difference between actual and predicted CPUE values.

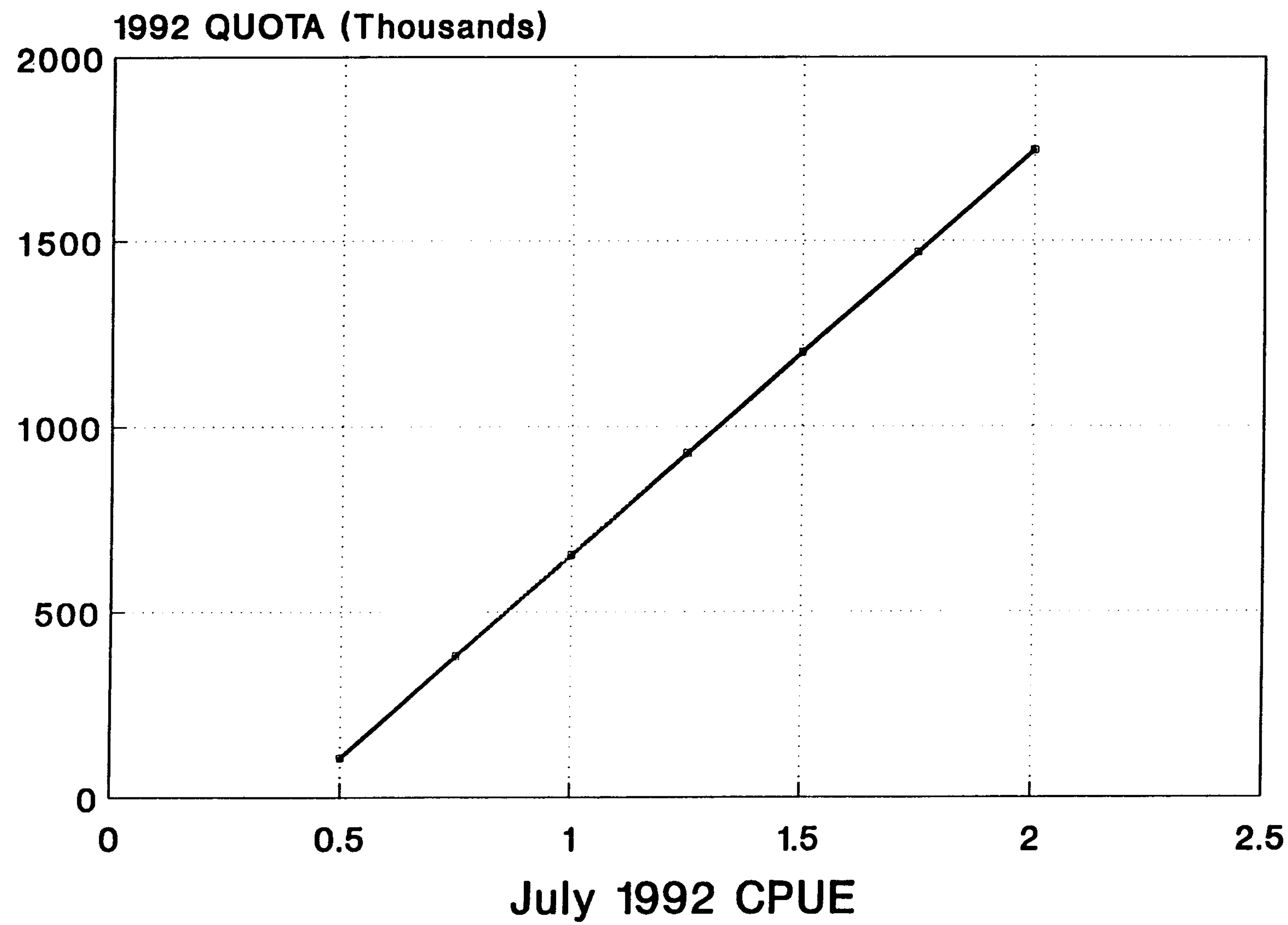

Figure 8.--Relationship between catch per unit effort (CPUE) and commercial quota as defined in Amendment 7 of the Crustacean Fishery Management Plan.

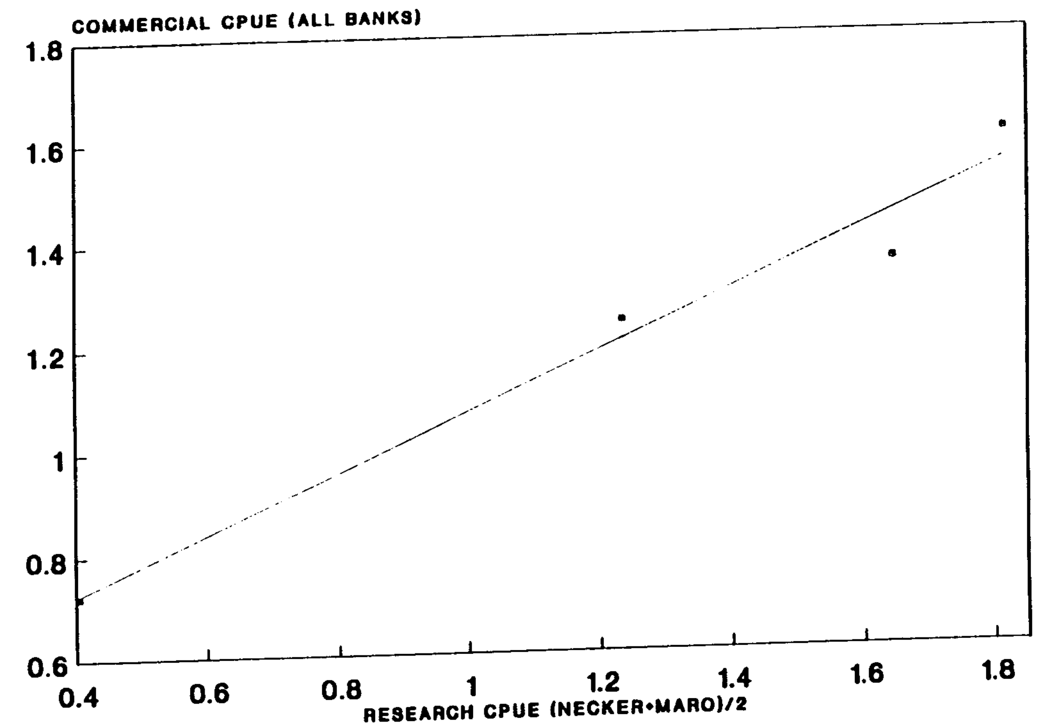

Figure 9.--Relationship between July research and commercial catch per unit effort in the Northwestern Hawaiian Islands.